Experiments and Observations on the various Alloys, on the specific Gravity, and on the comparative Wear of Gold. Being the Substance of a Report made to the Right Honourable the Lords of the Committee of Privy Council, appointed to take into Consideration the State of the Coins of this Kingdom, and the present Establishment and Constitution of His Majesty's Mint. By Charles Hatchett, *Esq. F.R.S.* Read January 13, 1803. [*Phil. Trans.* 1803, *p.* 43.]

From the introduction to this paper we learn, that in the year 1798, His Majesty was pleased to appoint a committee of members of his Privy Council, to take into consideration the state of the coins of the kingdom; and that this committee, having remarked the considerable loss which the gold coin in particular had sustained by wear within certain periods, had applied to Mr. Cavendish and Mr. Hatchett for their opinion what were the causes of this diminution, and what remedy might be applied to the defects by which it is occasioned. The mode of carrying on this investigation having been agreed upon by these two gentlemen, it fell to Mr. Hatchett's lot to perform the preconcerted experiments, and to draw up the account of them. Of this account, as it was too voluminous, and consisted of too many tables to be read in public, Mr. Hatchett has been pleased to communicate to the Society the Abstract, the reading of which took up the whole of this and the preceding meeting. On a general contemplation of the subject, it soon occurred that the inquiry was to be directed to two principal points;—1st, which of the two sorts of gold, whether that which is very ductile, or that which is as hard as is compatible with the process of coining, suffers the greatest loss under the general circumstances of friction;—and 2dly, whether coins with flat, smooth, and broad surfaces, wear less or more than coins which have certain protuberant parts raised above the ground or general level of the pieces. With a view of arriving at some certain data respecting these questions, three objects were principally kept in view, which gave rise to the three sections that compose the body of the paper. The first of these comprehends the chemical experiments, those which relate to the effects produced upon gold by the addition of different metals in certain relative proportions;—the second includes those experiments which relate to the different degrees of density observed in gold when differently alloyed;—and the third consists of those experiments which may be called mechanical, and which were expressly intended to ascertain the comparative wear of different kinds of gold by various modes of friction.

In the numerous set of experiments which are described in the first section, the effects of every metal and semi-metal upon the colour and ductility of gold were ascertained with all possible care and precision. All the semi-metals were found to affect the quality of gold too essentially, though in different degrees, to be ever used as alloys. And among the metals, lead in very small proportions was likewise found to render gold so completely brittle, as to be absolutely unfit for coinage. Tin was not near so pernicious; and iron, though it

turned gold much paler, yet did not materially affect its ductility. With respect to platina, one-twelfth of this metal, alloyed with gold, turned the latter metal to a colour similar to that of tarnished silver, but did not essentially diminish its ductility. Hence it is inferred, that a mixture of platina with gold, with a view to the adulteration of coin, need not be so much apprehended as was once the case, since the remarkable change of colour is a sufficient criterion to detect the fraud. The ultimate results of the experiments on copper and silver are, that these, either jointly or separately, are the only metals fit for alloys to reduce fine gold to the standard; care only must be taken that they, especially the copper, be of the purest sort; for which purpose, the fine granulated Swedish copper is recommended as the most proper. A mixture of the two metals ought to have the preference, as the colour of the gold is least affected by it.

2. In examining, in the second section, the specific gravity of gold made standard by different metals, single or mixed, it was found that several variations take place from causes independent of any defects in the hydrostatical operations. These are imputed to occasional imperfections in the interior texture of the mass during the processes of melting and casting; to a difference of density in parts of even the same mass; to the nature and position of the mould in which the metal is cast,—a long mould in a vertical position always producing a bar of metal more dense at the bottom than towards the top; to peculiar effects which certain metals produce when employed as alloys, and which are often very different from the results of calculation; and, lastly, to the effect of friction, which, as it is well known to generate heat, cannot, by the expansion it occasions, but affect the specific gravity of the metal. It hence follows, that as the specific gravity of metals is liable to be influenced by such a numerous variety of causes, it is almost in vain to expect absolute precision in the results of such experiments, and that a near approximation is all that can be demanded.

From the experiments made upon separate and entire ingots of gold, reduced to standard by silver and copper, separately and conjointly, it was proved that their specific gravities were as follows:—gold made standard by silver, 17·927; gold made standard by equal parts of silver and copper, 17·344; and gold made standard by copper, 17·157. Hence it appears that the specific gravity of our gold coin, which is generally alloyed by a mixture of the two metals, must be found somewhere between the two extremes just now mentioned; or, making allowances for small variations, arising from accidental causes, between 18 and 17.

3. In the third section, which treats of the comparative wear of gold when variously alloyed, we find, in the first place, an account of three modes or contrivances for ascertaining the quantity of abrasion by friction, according to the different circumstances of alloy and figure in the coins. In the first, two sets of coins were fastened, each in a frame, one of which was made to move backwards and forwards over the other with certain determined degrees of velocity

and pressure. In the second, 200 pieces of gold differently alloyed were inclosed within a wooden box, which was kept constantly turning round, until, by the continued rubbing and striking of the pieces against each other, and against the sides of the box, they were found to be perceptibly diminished. And in the third mode, the pieces to be examined were pressed against the rim of a flat horizontal wheel, by means of equal weights, so that by turning the wheel round, they all suffered an equal degree of friction. The part of the wheel against which the pieces rubbed was sprinkled or coated with some kind of powder, which was varied in the different experiments.

The general results of the many experiments made with this apparatus were, 1. That when equal friction, assisted by a moderate pressure, takes place between pieces of coin which are in each series of a similar quality, then, abrasion is most commonly produced in an inverse ratio to the degree of ductility;—2. That the contrary effect happens when pieces of different qualities rub against each other, the more ductile metal being then worn by that which is harder;—and 3. That earthy powders and metallic filings produce similar effects, and tend to wear the different kinds of gold in proportion to their respective degrees of ductility.

The practical inferences to be deduced from these results are, that pure gold, being extremely ductile, is not the most proper to be formed into coin; that gold, on the other hand, brought by its alloy to the greatest degree of hardness that will bear the manipulation of coining, will be so destructive to the instruments in the Mint, as to render the expense occasioned by this detriment much greater than the small saving that would accrue from the greater durability of the metal; and that hence gold of a moderate ductility must be that which is best adapted for coin, which degree of ductility will be found in the standard proportion of one-twelfth of alloy consisting of about equal parts of silver and copper.

Several incidental circumstances are mentioned at the close of this paper, some of which relate to the cause of the changes of colour in gold coins, which are ascribed to certain chemical changes in the alloy near the surface of the piece during the processes of annealing and blanching. We are also informed that the obliteration of the impressions on gold coins is not always attended with a diminution of weight, but that the supposed abrasion of the prominent parts is in fact a depression of those parts into the mass, bringing them to a level with the rest.

Upon the whole, our author concludes that the great loss which the gold coin of this kingdom is stated to have sustained, cannot possibly be attributed to any important defect in the composition or quality of the standard gold; and that all that can be said upon this subject is, that some portion of this loss may have been caused by the rough impression and milled edge now in use, by which each piece of coin acts and is acted upon by the others, in the manner of a file or rasp.